

THE
UTILITY AND APPLICATION OF HEAT
AS A
DISINFECTANT.

BY ELISHA HARRIS, M.D., OF NEW YORK.

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DISINFECTION BY HEAT.

THE UTILITY AND APPLICATIONS OF ELEVATED TEMPERATURES, BY STEAM OR BY DRY HEAT, AS MEANS FOR THE IMMEDIATE AND EFFECTUAL DISINFECTION OF PESTILENTIAL FOMITES, INFECTED VESSELS, AND CONTAMINATED APARTMENTS.

THE various applications of fire are among the most ancient and common methods employed for destroying specific infections, and for purifying contaminated places; but the practical objections to any destructive methods for disinfecting febrile *fomites* must naturally prevent them from being extensively adopted or faithfully applied as hygienic measures, except in rare cases and under the strictest police surveillance; and however effective may be the direct applications of fire or conflagration for the general purposes of disinfection, the following obvious objections preclude their utility and forbid their general adoption:—

1. The absolute loss of all the materials that are subjected to an incinerating or carbonizing heat.

2. The difficulty of concentrating deleterious miasmata and the atmosphere of contaminated places so as to subject them successfully to processes of combustion.

3. The excessive cost of maintaining fires for the purposes of the local disinfection of a contaminated atmosphere.

This last-named objection applies especially to what has popularly been supposed the readiest and cheapest method for disinfecting the pestilent gases of sewers and all large *cloacæ*; but not to domestic latrines and closets, nor to the deleterious gases of manufactories. On this subject Dr. Lethby remarks, in his interesting Report on Sewer Gases: “The value of *fire* as a disinfectant was known and has been recognized since the remotest times. . . . Powerful, however, as the agent is, it does not appear to be applicable to the destruction of sewer gases. . . . The cost of fuel for the furnaces (for the sewers of London) would not be less than £80,000, and perhaps it might reach to upwards of £200,000.”

Without recounting in detail the legendary story of pestilent atmospheres and contaminated places disinfected by the fires that Em-

pedoeles, Aeron of Agrigentum, or Hippocrates himself directed to be kindled, and which were accompanied with such apparently successful results as led Pliny to say "*Est et ipsis ignibus medica vis ;*" and without discussing the difficulties and doubts that have always characterized the various plans for disinfection, — it is the object of this paper to elucidate those feasible, economical, and safe applications of heat as a disinfectant, which by their simplicity, obvious practicability, and extensive utility, shall serve to commend this subject to the careful attention of all persons who are interested in measures for protection from, and the removal of, pestilent infection, whether of domestic or of exotic origin.

It should here be stated that the writer's attention was first drawn to the practical consideration of this subject by the responsible duties that devolved upon him as the chief officer of the New York quarantine hospitals during the prevalence of yellow fever and various infectious and contagious diseases then provided for at that establishment. The results of investigations then commenced, fully warrant the statements that follow in this paper.

In the able Report by Dr. Van Bibber, on Disinfectants, it is truly stated that "a disinfectant for yellow fever is a desideratum." The vast practical importance of discovering or inventing some reliable and practicable method for promptly destroying the virus of yellow fever and every other pestilent infection which is capable of being conveyed and propagated by ships is very forcibly presented in the statement of Dr. Van Bibber's *tenth proposition*. "*Prop. X.* The admission and knowledge of the fact that no disinfectant for diseases of this class exists, are at once the origin and the cause of the continuance of quarantine."

It is sufficiently manifest that if we were able to devise a simple and practicable method for absolute disinfection of the sources of pestilential diseases, the more onerous exactions of quarantine would speedily be set aside. But there are other and not less important considerations which render such a desideratum highly desirable; the welfare of the sick and the safety of all persons who may be exposed to either the exotic or the domestic *fomites* of pestilent maladies call for such methods of immediate and positive disinfection, while by the same means it might reasonably be hoped that the progress of such diseases, whether indigenous or imported, would be effectually arrested by the civic authority immediately upon their first appearance or localization.

The practical importance of such means for disinfection will be best appreciated by reflecting upon the immense tax that quarantines inflict upon commerce on the one hand, and on the other, by investigating the history and searching out the favorite *foci* of fevers in our cities and our hospital establishments.

Believing that the great desideratum of such a practicable and ready method of positive disinfection may be attained, we now propose —

1. To examine the evidences of the disinfecting power of high temperatures.

2. To institute inquiries respecting the minimum degree of steam or dry heat that may be relied upon for the purposes of disinfection.

3. Inquire respecting the highest elevation of temperature that various textile fabrics and staples, and the ordinary apartments and furniture of naval and domiciliary or hospital structures, may safely endure for the brief periods required for effectual disinfection.

4. Explain and illustrate the proper methods of applying both steam and dry heat for various purposes of disinfection.

First. The Evidences of the Disinfecting Power of High Temperatures.

As we desire to be understood to advocate the application of heat at temperatures compatible with the preservation of ordinary textile fabrics and such other destructible materials as are liable to become *fomites* and carriers of pestilent infection, it is proper that we should take, in evidence of disinfection, only such cases as have afforded reliable results, with known or limited increments of temperature. It is manifestly necessary that the degrees of heat resorted to be considerably below those temperatures that induce combustion, or even the slightest degree of carbonization. It will be borne in mind that the temperature of common flame is about $1,140^{\circ}$ F.; red embers about 980° F.; boiling water 212° F., and the lowest scalding heat at 150° F., and upwards; while dry vegetable tissues, as ascertained by M. Violette, enter upon the first stage of carbonization at a temperature of 150° centigrade, or 222° F.; ovens bake at from 320° to 400° F.; sulphur ignites at 560° , cane sugar melts at 320° , and liquid albumen coagulates at 145° F.

Though it might not be improper to indulge in some reasoning *a priori*, in the investigation of a subject like this, it is, perhaps, best that we depend solely upon the tests of experiment and the results of experience, in the argument pursued in this paper, which is designed solely for practical objects and the promotion of immediate and specific improvements in quarantine and hospital hygiene. But we cannot forbear noticing such strikingly suggestive facts as the following, viz: that all vegetable life is extinguished at a temperature far below that of boiling water, and that animal and organic life generally is destroyed by a comparatively brief application of heat that coagulates albumen, — that is, at about 145° F.; that all kinds of fermentative catalysis cease at a temperature below that which coagulates albumen; and, in short, that by the agency of an elevated temperature all processes and conditions in nature that bear any analogy to the incubation, propagation, and effects of pestilent infections, are arrested, controlled, or so modified as to warrant the inference at least, that all infections which are transportable, and all *fomites* of infection, might be rendered inoperative by means of high heat. Yet, until experiment or varied experience has demonstrated the practical truthfulness of this inference, we must appeal to rigid facts and observations.

The first and most commonplace fact which has been incontrovertibly established by experience, is this, — that in all places, and under widely varied circumstances, the boiling or the steaming of infected clothing has invariably proved to be an effectual means of disinfection; while in progress of the same experience, in almost every hospital or private washroom for such contaminated clothing, has been taught the

sad lesson that the process of simple washing, *previous to boiling or steaming*, is very hazardous work to the persons engaged in it. This we regard as an important element of evidence, derived from *common* experience wherever typhus, smallpox, scarlatina, or the exotic *fomites* of yellow fever have been exposed in washhouses or storerooms. We need not encumber this paper with narratives of particular instances illustrating this subject. Such instances are familiar to most persons who have observed the progress of infectious fevers in cities and large towns.

The special experience—some of which has been experimental—connected with certain public hospitals, may here be referred to, and although the amount of actual experimental experience is yet very meagre, it is highly instructive, and strongly corroborates the opinion that moderately elevated temperatures may be universally applicable for purposes of disinfection.

First, and perhaps the most conclusive of any single record of experiment and direct experience, we would mention the instances recorded by Dr. Von Busch of Berlin. That gentleman carefully narrates the history of a fatal epidemic of puerperal or childbed fever occurring in the Berlin Lying-in Hospital, during the months of February and March, 1851, and which obstinately clung to the wards even after a most thorough cleansing of the establishment. Again, for the preservation of their lives, the inmates of the institution were removed. Seeing the utter inutility of all the efforts that had been made to eradicate that domestic pestilence of the lying-in chamber, Dr. Von Busch then determined upon heating all the wards, for a brief period, to a temperature of 150° F. or upwards. In all the wards he steadily maintained a dry heat of from 52° to 60° Reaumur, during two consecutive days; all the beds, wardrobes, and hospital utensils being retained in the wards. The result was triumphant. The wards were immediately reoccupied with the same class of patients as before, and having the same individual liabilities to puerperal fever. But the pestilential infection had been completely banished and annihilated from the wards, and now the inmates of that maternity hospital lived to rejoice in the fruit of their labor.

Here was demonstrated the interesting fact that one of the most pestilent, persistent, and dreaded types of febrile infection was speedily and effectually eradicated by simply elevating the temperature of the infected apartments to 149°—167° F. by means of common stoves.

The value of this record is enhanced and its practical lessons confirmed by the recurrence of similar events in the same institution during the subsequent winter, when the same fearful malady again made its appearance there, and was as promptly and effectually driven from the wards as in the former instance, and did not reappear for a period of more than six months.*

No physician, who is familiar with the nature and habits of the puerperal infection will doubt the evidences here presented of the dis-

* See the "*Neue Zeitschrift für Geburtskunde*," p. 313, Berlin, 1852. See also, on the same subject, some remarks by M. Paul Dubois, M. D., in the *Gazette des Hôpitaux*, 1853; also, in the *Bulletin de Therapeutique*, Nov. 1853.

infecting power of dry heat in the wards of the Berlin Lying-in Hospital. Other means *might* possibly have been successfully applied to the accomplishment of the same end, but none so certainly or so economically. Thorough cleansing and natural ventilation had failed to free the wards from infection, and that is precisely what has again and again occurred in typhus, and in smallpox wards, and in apartments, houses, and ships contaminated with yellow-fever infection.

It is conceded that the puerperal infection is a perfect analogue of, if it is not exactly identical with the virus or infection of typhus, erysipelas, and hospital gangrene.* Hence we may justly infer that apartments or wards which have become infected with those maladies may be as readily disinfected by heat as were the wards of the Berlin Maternity Hospital.

The vast practical importance of some prompt and effectual method of disinfection from the local contamination of typhus, erysipelas, hospital gangrene, and all other febrile poisons in our hospitals, and in all apartments or places that become *foci* of infectious maladies, is so obvious that we cannot doubt that any such method, when shown to be practicable and safe, will be generally adopted by hospital physicians and sanitary officers.

The frequent recurrence of hospital gangrene, typhus, erysipelas, and puerperal infections in hospitals; the fatality of their operation; and their obstinate and insidious persistence in wards and sick-rooms, are events too painfully familiar to medical men. Even in the admirably conducted New York Hospital, on Broadway, we have known the infection of typhus or ship fever to linger persistently for days and weeks, in the frigid temperature of winter, with all the windows and doors widely open, after complete evacuation and the most thorough scrubbing, whitewashing, and renovation.

But to the proofs of the disinfecting power of an elevated temperature. It must be confessed that the cases that can be quoted as proofs are yet too few to afford the requisite conditions for satisfactory demonstration of the proposition we seek to establish in this paper. Yet we have a variety of facts to present, which afford very strong cumulative evidences of the universal applicability and the complete efficiency of heat for purposes of disinfection. And such is the value of these evidences and the vast importance of a practical application of such knowledge to sanitary works wherever there exist *fomites* or *foci* of febrile infection, that the writer of this paper deems it to be his duty to present all the reliable facts he has been able to gather, and he would present them in the light in which he has viewed them, even at the risk of being thought too hasty in his deductions.

Before proceeding to record the results of the direct experiments and special observations, which will tend to confirm those of Dr. Von Busch, and establish the truth of the proposition here advanced, the results of the writer's personal observations and experience may here be inserted.

During a protracted and instructive experience in the superintend-

* See an Essay on the *Causes and Propagation of Puerperal Fever*, by Prof. Joseph M. Smith, of New York, in the New York Journal of Medicine, Sept. 1857.

ence of the New York Quarantine Hospitals the following significant facts were noted.

During a period of nearly fifty years, the washing and drying of the contaminated clothing from hospital patients and infected vessels had been performed in the ordinary way without the use of steam. The diffusion of fatal fevers from those *fomites* of infection was notorious during that protracted period. Immediately after the introduction of steam-tubs for boiling, and a steam-heated chamber for drying the clothing, and obviously as a result of those improvements, the occurrence of infectious or quarantine diseases among the washerwomen of that establishment ceased,—or at least they occurred but very rarely, and then from sources to which the steam heat had not been applied.

Early in the summer of 1856, when large quantities of dunnage were ordered to the washhouse from vessels infected with yellow fever, I ascertained that the two washerwomen who were attacked with that malady had been handling and washing various articles of clothing previous to steaming or boiling them. Though those unfortunate washers might have contracted the fever elsewhere than in the wash-room, it was deemed expedient to use greater precautions against infection, and accordingly directions were given that all clothing, both from ships and hospitals, should be steamed in the closed tubs previous to being distributed to the washers. Infected dunnage and clothing continued to be received in large quantities for several months subsequent to that order, but no more cases of yellow fever occurred among the washers.

Again, in the summer of 1859, a floating hospital was placed under my superintendence for the reception and care of all cases of yellow fever and other pestilential diseases arriving at the port of New York. The practice of burning all dunnage, bedding, and other clothing from infected vessels having obtained favor with the authorities who witnessed the same expensive and unsatisfactory process applied to the entire quarantine establishment, it had been advised that a like summary method of purification be continued in connection with the hospital ship,—the famous iron scow for the burning of infected ships' clothing, bedding, and dunnage, being still in existence. Accordingly, no apparatus or provision of any kind had been placed on board for the cleansing or for the reception and proper care of infected ships' clothing, nor even for the washing and preservation of the clothing of the patients and their bedding. The hospital ship had already been placed at the yellow-fever anchorage,—twenty miles from the city,—and was awaiting the arrival of the sick with fever. Under these circumstances a washroom was, under my direction, hastily extemporized,—furnished with a copper steam-generator and capacious steam-vats, steam wash-tubs, etc. This apparatus was placed in one of the galleries that had previously been constructed upon the outside of the vessel amidship, and to the after end of each of which, entrance was made by the gangway outside, both from boats and the wards.

Into the steam-vats was thrown every infected thing received from vessels, as well as all hospital and patients' clothing, etc., that required

cleansing. All articles from infected vessels were received directly into the steam-chamber, from boats, without entering the ship itself, or in any manner exposing it or its inmates to the danger of infectious contamination; while in the wards of the hospital, a like safe regulation was adopted, requiring every article, as soon as soiled, to be removed to the steam-vats; and there all substances capable of being febrile *fomites* were instantaneously heated to the boiling point, or even a higher temperature. It will be observed that these arrangements contemplated the preservation of both the clothing and the wards from becoming *fomites* or *foci* of infection.

The prediction having been reiterated by many persons that the hospital ship would certainly become infected, and be in itself a focus of pestilence, we are happy now to record the fact that with twelve cases of yellow fever, and with twelve cases of other maladies far more liable to personal or fomite communication, there was not an hour of sickness among all the employés of the Floating Hospital during the six months it continued in service, though the washerwomen and ten of the other employés had never suffered from yellow fever, and had no specific protection from any disease except smallpox.

It is admitted that such limited and imperfect observations necessarily fail to answer the requirements of rigid demonstration, but they certainly go to augment and corroborate that cumulative evidence by means of which an absolute demonstration is to be eventually effected.

There have been instituted at various times and for different purposes certain experimental tests of the efficiency of heat as a disinfectant, that, like the experiments of Dr. Von Busch, have furnished results which are quite as instructive as those witnessed in the Berlin Maternity Hospital.

Some time ago, when engaged in an investigation of the history of efforts for the improvement and relief of quarantines, I was led to examine some very interesting and valuable papers by the late Wm. Henry, M. D., F. R. S., of Manchester, a successor and biographer of the distinguished Dr. Priestley. Dr. Henry's writings on this subject were based upon special and ingenious experiments and inquiries instituted by him as early as the year 1824, and the results of which were communicated to the Philosophical Magazine in the years 1831-32.

By a series of scientific inquiries and most reliable and exact experiments that learned gentleman attempted to determine,—1st, what elevation of temperature “cotton and other substances likely to harbor contagion” of the plague or typhus might sustain without injury,—the heat being applied both to the raw staples and to their various fabrics;—2d, by the application of the proper tests “that in at least some one unequivocal instance, contagious or infectious matter should be proved, by actual experiment, to be destructible at that temperature.” and which previous experiments had proved would safely be endured by the pestilent *fomites* for the time that should be requisite for absolute destruction of the febrile virus.

The experiments with material substances were extended to a considerable variety of articles, both raw and manufactured. The fol-

lowing brief summary embodies the more important results of those observations and tests :—

1.—A quantity of raw cotton, subjected to a dry temperature, of 190° F. which was steadily kept up in the inner compartment of a double vessel heated by steam, during a period of two hours.

2d.—A quantity of cotton yarn, No. 40, subjected to the same process and temperature as the cotton staple.

Result.—The raw cotton became “fuzzy” on account of the loss of its natural moisture, and from the same cause the strength of the yarn was for the time impaired, but “after being left during two or three days in a room without fire, a great change had taken place in its appearance, and it was found, on trial, that the cotton was as capable of being spun into perfect yarn as that originally employed; on accurate trial of the twist which had been spun from it, a hank supported fully an equal weight with a hank of the same fineness that had been spun from cotton fresh from the bag. This fact, established by repeated experiments, proves that with the recovery of its hygrometrical moisture, cotton which had been heated, regains its tenacity, and becomes as fit as ever for being applied to manufacturing purposes.”

Dr. Henry then goes on to state that the “articles of cotton, silk, and wool, after being manufactured, both separately and in a mixed state, into piece goods, for clothing, were next submitted to the same treatment. Among them were several fabrics which were purposely chosen, of the most fugitive colors and delicate textures. After being exposed three hours to a temperature of 180° F., (dry heat,) and then left a few hours in a room without fire, they were pronounced perfectly uninjured in every respect. Furs and feathers, similarly heated, underwent no change.” In a subsequent communication, Dr. Henry states that he has since found that in most cases the temperature may safely be raised forty or fifty degrees higher than was used in his first experiments, thus allowing a dry heat of about 220° Fahr.

So much for the question of safety to the goods exposed to any degree of heat that might be required to purify them under any circumstances from pestilent infection. In another section of this paper we shall again refer to this subject, and offer several illustrations in confirmation of these conclusions of Dr. Henry.

In our present inquiry, as well as in the experiments of the learned gentleman from whom we have just quoted “the most important point to be ascertained, and that on which the utility of the inquiry hinges, is whether a temperature below 212° Fahrenheit is capable of destroying the contagion of *fomites*.” With a clear apprehension of the intricacies and difficulty that must necessarily attend any reliable measures for determining this question, Dr. Henry commenced his first series of experiments for this purpose by various tests of the effects of heat upon the contagious element or principle of cow-pox. His tests were rigidly reliable, and by them he satisfactorily established the fact “that the infectious matter of cow-pox is rendered inert by a temperature not below 140° Fahrenheit; from whence it was inferred,” says Dr. Henry, “that more active contagions are probably destructible at temperatures not exceeding 212° F.” He justly adds, “This proposition it was obviously within the reach of experiment to determine.”

Acting upon this conclusion, Dr. Henry entered upon a series of wisely directed experiments and tests to determine the disinfecting power of heat upon the personal *fomites* of typhus fever and scarlatina. He made three experiments with personal *fomites* of typhus. Three flannel shirts taken on three successive days from a most strongly marked case of contagious typhus, were subjected to a heat of 204° F., for an hour and three quarters. These personal *fomites*, thoroughly charged as any garment could be, with the infectious or contagious principle of the fever, were put to the following tests: The first flannel jacket was placed directly under, and within twelve inches of, the nostrils of a person engaged in writing, and who was excessively fatigued from previous exercise and had observed an unbroken fast for eight hours; this test of exposure was continued for two hours. The second jacket, was worn next the body by a person for two hours; while the third jacket, after the exposure to heat, "was kept in an airtight canister for twenty-six days, with the view of giving activity to any contagious matter "which might possibly have escaped decomposition." It was then placed within twelve inches of the face of a person for four hours; "a gentle current being contrived to blow upon him from the flannel during the whole time." In none of these instances was the fever communicated, and no injurious effects were experienced.

Dr. Henry remarks that he does not lay much stress on so limited a number of facts; but it is our purpose to record all the more important tests that we have ascertained to have been instituted in illustration of the questions connected with the subject of disinfection by heat. We will therefore continue the narration of still further experiments by Dr. Henry, who certainly appears to have entertained very clear conceptions of the conditions required for a scientific demonstration of these vexed questions. It may here be stated that his first series of experiments—those relating to vaccine virus—were so conducted and varied as to afford the most absolute demonstration of the fact that a temperature of 140° F. renders the freshest vaccine material completely inert. The tests resorted to by that gentleman for typhus disinfection cannot, from the very nature and complexity of the conditions involved in the dissemination of typhus poison, be regarded as conclusive demonstrations; they are, rather, cumulative proofs.

Scarlatina was the third type of specific febrile infections that Dr. Henry subjected to his varied tests; and in that malady, he says, "we have a disease admirably adapted for furnishing the necessary evidence. No one doubts of its being infectious.* Perhaps, indeed; of all dis-

* Dr. Henry belonged to that distinguished class of men whose minds are trained in a more rigid school of inductive philosophy, than the class of medical dogmatists who reject at sight all evidence, logic, and fact, that may not chance to accord with their own theories and dogmas. Among the latter class are those physicians who summarily reject all evidence respecting febrile infections, and boldly declare that "scarlatina, typhus, puerperal fever, etc., are no more infectious than a common cold." Dr. Henry believed in both the mediate and the immediate communication of typhus and the exanthemata.

eases with which nosologists have arranged it (the *exanthemata*), it gives birth to the most active and durable contagion. . . . In the state of *fomites*, this species of infection has lain dormant for many months."

Having found a patient suffering from "*scarlatina anginosa*," Dr. Henry proceeded to institute the most reliable tests, by means of flannel waistcoats, and the persons of susceptible and delicate children that had not previously had the disease; and following up these experimental tests, he was favored with the opportunity of securing other waistcoats from three other young persons who, in succession, had been infected in regular sequence, by communication with each other.

The infected waistcoats were heated to a temperature of about 204° F., and, with the exception of two out of a large number, each was applied and kept immediately upon the person of some young and susceptible subject. Two of the garments were kept closely sealed up for several days, and, after being heated, were applied in a similar manner.

In none of these cases was the *scarlatina* communicated, or any effect produced, though the children were attentively examined every day, in order that no slight symptom might pass unobserved." In conclusion, Dr. Henry says: "The experiments which we have related appear to me sufficiently numerous to prove *that by exposure to a temperature not below 200° F. during at least one hour, the contagious matter of scarlatina is either dissipated or destroyed.*"

There are many reasons for believing that the activity of the typhus, *scarlatina*, or any other febrile infection may be entirely destroyed at a temperature far below 200° F.; but with the limited amount of positive knowledge we possess relating to this subject, it would justly be regarded as an act of criminal temerity for the medical inquirer and experimenter, even for the sake of the profoundest scientific discoveries, or for the probable future advantages to humanity, to expose any human being to the hazard of being brought *needlessly* near to the point at which it were believed that a fatal or dangerous febrile poison would be communicated. It is always easy to obtain a local temperature of 200° or 212° F. in any apartment or apparatus that would be required for disinfecting pestilent *fomites*; and, as was shown by Dr. Henry's experiments, with the various textile fabrics and their staples, they endure such a temperature without injury.

Though we have already extended this *résumé* of Dr. Henry's experiments much beyond the limits we had assigned for the purpose, we cannot forbear the following question, which he proposes:—

"The circumstances under which the experiments were conducted render it, I think, demonstrable, *that the disinfecting agency belongs to heat alone*;" (i. e. in these tests;) "for the receptacle in which the infected waistcoats were placed having in every instance been closed, change of air could have had no share in the effect. The phenomena, then, are reduced to their simplest form; and the results put us in possession of a disinfecting agent the most searching that Nature affords;—one that penetrates into the inmost recesses of matter in all its various states."

The writer of this paper commenced his inquiries without any definite knowledge of Dr. Henry's experiments, and after a partial investigation of the various questions connected with the problem of disinfection by heat or steam, the great importance as well as difficulty of direct experimental tests led him to examine very critically the records of such experiments, bearing upon the subject, as had been instituted at various times and for a variety of purposes; and although, now, after a protracted and somewhat thorough investigation of the various questions in science and experience connected with the subject, he feels prepared to announce his full belief and confidence in the disinfecting powers of elevated temperatures, it seems very desirable that further inquiries and tests should be instituted with reference to a more clear and popular demonstration of the conditions, means, and special applications of heat, required for the more common purposes of disinfection. And it should here be stated that the main design of the writer in presenting at this time the views embodied in this paper, has been particularly to invite such attention, inquiry, and practical tests, from various quarters and by such persons as will most satisfactorily establish the facts of the practicability and general utility of the methods of disinfection herein proposed.

If it can be demonstrated that a temporary application of heat, either by steam directly applied, or by heated air, at any temperature not higher than 212° F., will certainly and effectually disinfect all varieties of pestilent and febrile *fomites*, and contaminated apartments, then it may safely be asserted that the time is near when such *fomites*, and the apartments of infected vessels, hospitals, and infectious fever-chambers, or pestilential *foci* and *fomites* of every class will be systematically and effectually disinfected by some ready method of applying such degrees of heat as may be required.

It is not to be supposed or desired that heat will be a substitute for thorough ventilation, cleanliness, and hygienic regimen; but that its applications will be resorted to when and where those essential measures of hygiene are insufficient for the removal of localized febrile infection. The localized infectious cause of yellow fever in material substances, in domiciles, or in ships; the inhering poison of puerperal, typhus, and other specific infections in hospital wards and close sick-rooms; and the immediate and safe disinfection of pestilent *fomites* of every class, require such an easily applied, controllable, and permeating agency as an elevated temperature for their purification.

It has long since been shown, by greatly varied experiments and innumerable incidental observations and tests, that none of the chemical disinfectants can be relied upon except as deodorizers, and as adjuvants to ventilation and cleansing. The *chlorides* and the *manganates*, even, fail of answering the conditions required for the immediate and absolute disinfection of pestilent *fomites* and contaminated apartments.

If heat is proven to be an effectual disinfectant at about 200° F., then its superiority is demonstrated beforehand; for it is susceptible of ready application to every inanimate thing that is liable to imbibe

or convey specific pestilential virus; and this, even to the richest saloons,* the closest apartments, and the most hidden and inaccessible portions of any vessel or warehouse. In the practical applications of heat we have an agency the most searching that Nature affords; and, as remarked by Dr. Henry, "one that penetrates into the inmost recesses of matter in all its various states."

It is true that there may be found some practical difficulties in the application of hot air or dry heat in certain inaccessible places of a vessel, and to certain materials that possibly might imbibe febrile poison; but in all such cases and for all such materials, *steam* may safely be resorted to, and with very great economy, dispatch, and satisfaction. By virtue of the almost unlimited expansive property of high steam, together with its remarkable property of latent heat,—estimated at about 1,000° F. when at its ordinary temperature of boiling water,—this subtle and elastic element readily conveys and inflicts a scalding heat wherever it is allowed to escape into closed apartments, while by its properties of latency and almost infinite expansiveness it will penetrate, more certainly and effectively than any other agent can, every porous substance and the most hidden and intricate openings or crevices where infectious poison might possibly be localized.

It is to be regretted that the utility of steam or heat in some other form has not been experimentally and extensively tested on board infected vessels and in contaminated apartments; for it is in such vessels and apartments the question of the applicability of heat to the practical purposes of disinfection may most satisfactorily be demonstrated. All admit—contagionists and non-contagionists alike—that pestilent febrile poisons may not only be generated in foul ships, and there become endemial, but that an endemic cause of certain maladies is liable to become obstinately fixed and perpetuated in such places; while, on the other hand, the questions relating to *fomites*, so-called, may forever remain *sub judice*, or, at least, subject to doubts. As, in a somewhat extended reading of nautical medicine, we have met with no very satisfactory instances of the application of heat to purposes of disinfection in ships, we wait with interest, but with little doubt, the practical and triumphant results of this mode of purification.

The writer last year suggested to the Quarantine Committee of the New York Chamber of Commerce the propriety of instituting direct experiments with heat in vessels known to be contaminated. The proposition was received with favor, and it is hoped that it may yet

* The injuries liable to be produced upon various rich goods or in nicely furnished apartments by particular increments of heat, whether by steam or dry heating, may readily be estimated beforehand. In no case could it ever be required to raise the temperature to the degree that produces carbonization, which, as M. Violette has shown, does not even commence at a point lower than 222° Fahrenheit. The accidental application of scalding steam to the costliest furniture and upholstery of the rich saloons, in steam vessels, has too frequently demonstrated that the steam-heat which instantly destroys animal life, leaves those gorgeous apartments and their furniture comparatively unharmed.

be acted upon by that distinguished and public-spirited body. The opportunities for such experimental tests in naval disinfection are often presented in the port of New York.

The most striking instance of the supposed disinfectant effect of heat in a badly infected ship was many years ago narrated by the distinguished Dr. William Ferguson, at that time Inspector General and Chief Medical Officer in the Leeward and Windward Islands. It is to be regretted that the particulars of the case are not fully recorded, but in the official documents accompanying Dr. Ferguson's communications to the Royal Medico-Chirurgical Society, (See vol. viii. of the *Royal Med. Chirurg. Trans.*) the following extract appears from the evidence then taken respecting the occurrence of yellow fever on the transport ship "Regalia," in which that fever had become endemic, and prevailed with frightful mortality. The record states "that whilst at English Harbor she underwent fumigations as ordered by Commissioner Lewis, without the least effect in arresting future attacks or their fatality; and that it was not until after her arrival in Carlisle Bay, where she *was completely cleared, and with her hatchways closed, her whole hold exposed to the concentrated heat of many stoves, that fever ceased.*"

Whether this happy and immediate disinfection of that unfortunate transport was effected solely by the high degree of heat to which every compartment of the vessel was subjected, we will not attempt to determine; but the facts in the case are very suggestive of the positive utility of heat in such cases. And before dismissing this topic, we desire to solicit the contribution of any facts that may have been observed, or that are known to any gentleman connected with naval or mercantile marine service, or that may have come to the knowledge of others into whose hands this paper may fall.*

* The following interesting and suggestive facts were elicited by the discussion of this paper in the Convention.

BROOKLYN, N. Y., July 10, 1860.

MY DEAR DOCTOR: I cheerfully comply with your request to give you a circumstantial account of the instances I mentioned in our discussions upon your paper, in Convention at Boston, in illustration of the disinfectant properties of steam for yellow fever.

While I was an Assistant Surgeon in the Navy, and during the epidemic of yellow fever which prevailed in the U. S. Naval Squadron, in the vicinity of Vera Cruz, during the summer and autumn of 1847, the U. S. steamer "Vixen" was one of the earliest and one of the worst-infected vessels of the squadron. This vessel had done a good deal of river and coast service, was filthy and infested with cockroaches and rats. I was ordered to the "Vixen," from other service in the squadron, in the early part of December, and there had charge of the latest cases of yellow fever during that season of the epidemic. During the winter season, while the "northers" prevailed, there was a cessation of *yellow fever*, though we continued to have a large sick list composed of tedious convalescents and frequently recurring febrile complaints. On the return of hot weather, in the following May, (1848,) there being no immediate prospect of our going north, and in anticipation of an early return of yellow fever in our then fitting condition, it became expedient to "break out," as far as practicable while on service, and paint ship. Before undertaking this, the commander, James H. Ward, Esq., resolved on a final effort for the extermination of the vermin, by *steam*. Everything susceptible of injury was taken on deck, the hatches closed and steam turned in below decks. This was kept up for two or three hours, and with

In the foregoing pages we have endeavored to present a practical view of the more important questions connected with the subject of immediate disinfection by heat as a means of simplifying and facilitating the necessary operations of quarantine; and likewise as a means peculiarly adapted to the destruction of all the domiciliary *foci* of infectious fevers. The practical importance and value of the full attainment of such a desideratum cannot well be over-estimated. Commerce alone would be benefited to the extent of many millions in a single port like that of New York, during a year when yellow fever prevails;

such a head as to completely permeate every crevice. After steaming, there was a thorough seraping, whitewashing, and painting. From this time forward there was a decided improvement in the health of the crew; — *no more fever cases occurred.*

About a month subsequent to the steaming of the "Vixen," the gun-boat "Mahones" Commander W. D. Porter, Esq., having been on a surveying expedition up the Tuxpan river, returned to the anchorage at the mouth of the river, and telegraphed for me to visit the sick. The "Mahones" had no medical officer. *There I found three cases of yellow fever, and, within a few days, four others.* The "Mahones" was a captured vessel; had never been off that coast; was filthy and infested with vermin. The salutary effects of the steaming on board the "Vixen," both for vermin and *fomites*, — no unusual associates, by the way, were so apparent that the same process was forthwith advised and applied, by means of the "Vixen's" engine, to the "Mahones," and, as in the first case, vermin and fever both ceased to live.

These vessels continued on service in the vicinity of Vera Cruz until the following August, when they both came into Norfolk, in the very height of hot weather. The "Mahones" was there laid up and subsequently sold; and the "Vixen," after remaining three weeks, without "breaking out," was transferred to the Coast Survey Service in the Chesapeake Bay for the remainder of the summer. In neither of these vessels was there any return of the fever.

About the same time that the "Vixen" and "Mahones" arrived at Norfolk, the frigate "Cumberland" and the steamer "Scorpion" arrived at New York. The "Scorpion" was at once put in quarantine on account of recent cases of yellow fever; and the "Cumberland," not having had any cases since the previous season, was, after a few days' delay, permitted to go up to the Navy Yard; but on the beginning the work of "breaking out," yellow fever also broke out on board, and she was ordered down to quarantine until cold weather. The "Cumberland" and "Scorpion" were from the same squadron with the "Vixen" and "Mahones," but more commodious, better ventilated, and in every respect in better condition for health, except that they *had not been steamed.*

Truly yours,

A. N. BELL, M. D.

E. HARRIS, M. D., New York.

The foregoing narrative is replete with practical suggestions and instruction, but to get the full force and significance of the facts Dr. Bell has so clearly stated, we need to take into consideration the fact that almost every other vessel than the "Vixen" and the "Mahones" became infected with the active cause of yellow fever. As was illustrated in the case of the "Cumberland" and the "Scorpion," that infection was all-pervading and remarkably persistent, even in the best class of the vessels then employed in the Gulf Squadron. The returning vessels from that squadron, which, during the later months were anchored with the "Cumberland" and the "Scorpion" at quarantine in the Bay of New York, diffused their pent-up pestilential miasmata to the shores of Staten Island with fatal effect. The application of steam in the two vessels mentioned, and the instant cessation of fever, together with its non-appearance after protracted service, could scarcely have been coincidences. The *post hoc ergo propter hoc* seems for once truly illustrated in those instances. We would invite particular attention to the simplicity and effectiveness of the methods adopted for the introduction of the steam in those vessels.

for in every instance of real or reasonably suspected pestilential contamination of any vessel or any number of vessels arriving in port, the time required for debarkation and storage of the cargo at the quarantine warehouses, together with the delay of the vessel in undergoing the process of disinfection by steam, and the subsequent preparation for sea, would not occupy more time than is required for healthy vessels under ordinary circumstances. It is universally conceded that, if any quarantine, or regulations in the nature of quarantine, are required for the public safety, then are special quarantine warehouses and docks required for rendering quarantine thoroughly effectual without serious embarrassment to commerce. Nothing could be more conclusive on this point than the statements made on this very subject in McCulloch's Commercial Dictionary. In connection with all such warehouses and docks, the requisite apparatus for generating and applying steam and dry heat could readily be supplied and kept in constant readiness.

The purpose of this paper does not require that the writer should enter into any specifications respecting the proper appliances and the exact methods to be resorted to for disinfection by heat. The experiments of Dr. Von Busch, in heating the wards of his hospital with stoves, and the trial of the same plan in the cabins and compartments of the transport ship "Regalia," together with the varied experiments of Dr. Henry, with dry heat, have fully demonstrated the feasibility of simple means for securing the required elevation of temperature for disinfection; while various experiments made with, and numerous explosive accidents from steam have sufficiently established the fact that almost any apartment or space in a house or a ship may be exposed to the scalding heat of steam without serious injury. On this point, as well as with reference to the absolutely scalding and life-destroying effects of steam suddenly injected into closed apartments, nothing could be more suggestive than the painful results of the bursting of steam cylinders, etc., in manufactories and steam vessels. But we need not enlarge upon this subject. It is not our purpose to arrive at final conclusions by means of hasty generalizations from such imperfect data as are now at our command. The writer desires to invite attention to the questions stated in this paper, and, if possible, elicit such experimental and scientific researches, as will lead to well understood and practically valuable results. Hidden and mysterious as the nature of pestilential miasmata and their modes of operation now seem to be, it is not improbable that experimental science may yet make us sufficiently acquainted with their strange phenomena to enable the human mind successfully to grapple with their subtle causes, or by scientific and ready applications, to overcome and destroy their deadly properties. But such desirable triumphs over the active elements of pestilential poison are not to be attained without patient efforts of research, observation, and experiment. The several experiments referred to in this paper, and the valuable reports of M. Tardieu, Munspratt, and Van Bibber give very decided indications of approach to the grand desideratum of a reliable and instantaneous method of disinfection for all transportable or *fometic* febrile poisons. The writer of this paper has ventured to express his firm conviction that, for practical purposes, an

elevated temperature, applied either by steam or by dry heating, will be found, upon trial, to afford the most effectual agency that can be employed for the purposes required at quarantine establishments, and for the disinfection of ships, hospital wards, and other domiciliary *foci* of infectious fevers, and for the purification of all pestilential *fomites*.

In the present imperfect state of scientific knowledge relating to the essential proximate causes of specific constitutional diseases, and the intimate nature and chemistry of febrile miasmata and their *modus operandi* in the production of fevers, it would be impossible to give a scientific solution of the problems connected with the processes of disinfection. It is true that most if not all of the disinfectants are *oxidizers*, some of them inducing the development of *ozone*; most of the chemical salts used as disinfectants serve to fix, neutralize, or recombine noxious compound gases; but in the absence of any evidence that the proximate or infectious cause of pestilent fevers consists in *substantive miasmata*, or in particular gaseous compounds, we are yet compelled to rely mainly upon such individual and empirical facts as have been or can be established by actual observation. Such are most of the facts relating to steam or heat as a disinfecting agency; though, as stated in a former section, there are many analogies so instructive and applicable that they may be taken into consideration in our reasonings and experiments regarding disinfection by heat.

The adoption of improvements in medicine and in art must not wait for the settlement of the exact questions and problems that physiological and pathological chemistry propose, for many a lance may be broken between scientific theorists and experimenters, ere an enduring philosophy is wrought out. The square of the hypotenuse had long been estimated, and its geometrical relations had long been applied to practical purposes in daily life, ere Pythagoras could offer a holocaust, in his gratitude and rejoicing at the discovery of a scientific solution of the facts so long applied by means of the legs and the hypotenuse of the right-angled triangle. The specific powers of *quinine* have been acknowledged and applied in all parts of the world since the first manufacture of that article by Pelletier and Caventou in 1820, but a strictly chemical or scientific demonstration and understanding of the *modus operandi* of that remarkable remedy has but just been commenced, and may not be satisfactorily established until forty years more have been spent in researches, experience, and experiment. So it may be with the chemistry and science of disinfection; we may not by *a priori* reasonings nor direct chemical study immediately find out the true interpretation of the phenomena and the facts that now invite our investigation.

Hitherto it seems to have been conceded that thorough ventilation is "an indispensable and potent auxiliary to disinfecting substances;" and it actually has always proved far more reliable and effectual than all chemical disinfectants. But we would invite attention to the fact that in the disinfection or destruction of the domestic *foci* of contagions or infections, as well as in the treatment of exotic infections, it is very desirable, oftentimes, to prevent any diffusion of the localized poison of pestilent disease, whether in apartments or in material sub-

stances. If heat is demonstrated to be a disinfectant, then it is peculiarly applicable to this important class of cases in which its powers are required. Beyond such purposes, it should not be proposed to extend its applications, and for all other sources of *febrile miasmata* we already possess reliable remedies and prophylactics.

In the statements contained in this paper, we have not deemed it expedient to enter upon the discussion of the question, "What constitute pestilential *fomites*?" nor have we attempted any new definition of the distinctive natures or the essential properties of infection and contagion, but the writer wishes to be understood as a rational believer in both infection and contagion; and in order that his statements and opinions may not be misunderstood or misapplied, he would here briefly enunciate, in his own language, what he conceives to be the simplest and most widely accepted definition of those much abused and ignorantly derided terms. It is the definition which we desire to have understood in the use of the terms in this paper. INFECTION is the contaminating or morbid impression and effect of a specific cause of disease, operating in or upon the living body, usually originating without the body, and being propagated independently of it; but in a few limited types of disease, that cause originates *within*, and is propagated *by* the animal system; diseases of the latter class are *contagious* as well as infectious. CONTAGIOUS diseases originate in, or are reproduced by the living body, and *can be communicated from person to person*.

In the language of Dr. Pickford, "*Contagion* may therefore be designated a specific virus originating *within* the body." But *infection* is a generic term, including a great variety of causes of disease. Some of those causes are transportable from place to place, and it is with such we have to deal at our quarantine establishments, and wherever there are *foci* of infectious fevers, — be they contagious or non-contagious.

The extent to which material substances are liable to become *fomites* or absorbers and enkindlers of specific diseases has never been very accurately defined; yet the general law regarding pestilential *fomites* appears to be this: that any textile or porous inanimate substance, not subject to active chemical changes, may, under certain circumstances of exposure, imbibe and retain for a time the proximate diffusible cause of certain infectious maladies; with but *few exceptions*, such transportable febrile poisons or infections are those that have been generated by *contagious* diseases.

There are but few instances known in which ordinary cargoes of merchandise have become in any degree contaminated so as to propagate or diffuse the cause of fevers. Indeed, it may safely be asserted that yellow fever, cholera, and the plague, are the only diseases known which are believed to be liable so to contaminate an entire ship as to render it expedient to institute quarantine restrictions against the importation of infection in such cargoes as arrive in vessels on board of which pestilent maladies have prevailed. But the multiplied evidences of the importance of quarantine restrictions for vessels and cargoes from ports where yellow fever is endemic,

render it necessary to devise some effectual method for the relief of ships and their contents from those delays which have hitherto been so embarrassing and injurious to commercial interests. The utility and application of elevated temperatures for the disinfection of vessels, dunnage, and the particular kinds of cargo that are liable to retain and diffuse the transportable cause or virus of yellow fever, is the subject that has elicited the investigations and arguments pursued in this paper. We have endeavored to state what is known and applicable, also what is uncertain but very desirable to be known, and what questions are, in the present state of human knowledge, beyond the reach of experiment.

As regards the utility of special disinfection to arrest Asiatic cholera, all is problematical, fresh air having hitherto been the only effectual disinfectant; but as simple ventilation may not actually destroy the propagating cause of cholera, it is desirable that means should be used for the immediate and complete arrest and destruction of at least all exotic infection of that malady, instantly upon its arrival at our quarantine stations. Indeed, it would be equally desirable to arrest or prevent the localization of that pestilence at its favorite haunts in the large towns in which it makes its earliest outbreaks; and for the accomplishment of such purposes, it may yet be demonstrated that artificial heat is the most reliable agent.

The Oriental plague is known to disappear under a moderately high natural temperature, and the fact is demonstrated beforehand that all germs of that terrible pestilence would be instantly rendered inactive by a temperature which could be readily and safely applied to anything that is liable to become the *fomitic* carrier of the malady.

From the foregoing statements may be seen the objects which have prompted the preparation of this paper. Imperfectly and hastily prepared as it is, the author would hope that it may incite to accurate and practical observations and inquiry among gentlemen who enjoy the needed opportunities for prosecuting experimental investigations.

It must not be supposed that such investigations will require any very extensive and costly apparatus. Dry heat is attainable by means of stoves or coils of steam-pipe; and for direct steam heat a portable steam generator, sufficiently powerful to heat any ordinary apartment to 200° Fahr. can easily and cheaply be called into requisition; and for the instantaneous steaming of infected ships, the steam boilers of the more powerful steam-tugs about our harbors would, with the aid of a few simple appliances, be sufficient for such purposes.* However, it must be borne in mind that there should be entire *accuracy* of scientific observation in all the tests and applications of both steam and dry heat, even in the roughest trials of those methods of disinfection in ships or in hospital wards. This may be attained by a proper use of self-registering thermometers.

The application of heat to the disinfection of valuable goods should be so nicely attended to that no damage to the merchandise would be incurred, and at the same time no defect allowed in the process. Dr.

* See Dr. Bell's letter, p. 15.

Henry used a double-sided metallic chamber surrounded by steam or hot water; but we apprehend that it may, in many instances, be found desirable to make a direct application of steam. In illustration of the fact that steam at a high temperature may be so applied to delicate materials with facility, and without damage to the articles, we will refer to a familiar and suggestive instance of its use in the preparation of silk cocoons. The facts are communicated, at our request, by a gentleman who recently visited the celebrated silk-reeling establishment of J. G. Scott, Esq., in the village of Shemlan, near the foot of Mount Lebanon, in Syria. In that immense establishment vast quantities of silk cocoons are received from the surrounding country, and in order to preserve them in a suitable condition for reeling, it is necessary to destroy the vitality of the *chrysalis* immediately upon the reception of the fresh cocoons at the depot. This is instantly effected by the application of steam in a scalding chamber, so constructed as to permit the ingress and egress of metallic wicker-work cars, upon which the cocoons are so arranged or stowed as to permit the immediate access of the steam, which is injected at will through the pipes that cover the bottom and sides of the chamber. By means of the railway arrangement, a constant succession of cocoon-cars are kept passing through that steam chamber,—each little cargo being detained and subjected to the steam heat in the closed chamber a few minutes,—for the destruction of the *chrysalis*, which each cocoon so snugly incloses in its impermeable envelope of compacted silken threads.

These nicely adjusted processes illustrate at once the effectiveness of steam as an agent or means for applying heat to inaccessible places, as well as to the most delicate materials, with entirely definite and satisfactory results,—as a destroyer of animal vitality. As the doctors would say, it answers all the requisites of a curative agent,—*tuto, cito, et jucunde*.

Whether it will ever be desirable or necessary to apply steam or heat by any means, to cargoes of cotton, woollens, etc., may be regarded as very doubtful; for, with a proper system of quarantine warehousing, such special disinfection need not be extensively resorted to, even if cotton and wool arrived in an infected condition. At the most, it might only be desirable to insure the disinfection of samples,—which could readily be effected.

In the case of *samples* infected with yellow-fever, and for certain articles or particular packages of merchandise, refrigeration would, perhaps, be the better method of disinfection; but for typhus, cholera, smallpox, and the plague, cold would not answer the conditions of disinfection: Heat would answer all the conditions; and fortunately we know of no articles of merchandise liable to become *fomites* for communicating the latter diseases, that might not safely and properly be subjected to steam heat; while in the case of the ordinary cargoes from places within the yellow-fever zone, we know of no articles of merchandise liable to retain infection,—which might not be subjected to either heat or cold with equal impunity, and, so far as regards the virus of yellow-fever, with equal success. And it may

here be remarked, that the same disinfecting chamber required for the process of disinfection by steam heat, would, with the simple addition of refrigerating tubes and plates, be perfectly adapted to the requirements of refrigeration. The conditions required for either process have already been fully demonstrated in various experiments for other objects.

The limits we had assigned to this paper will not admit of any further statements or illustrations. The writer's main design will have been accomplished if his suggestions are made to promote practical improvements in our means for controlling the *fomites* of infectious maladies. The aim has been, in all the foregoing suggestions, to propose practicable measures for insuring an absolute destruction of the pestilent property of all localized infection, without loss or damage to the materials or the apartments that retain the virus of disease, and also to propose a rational method for effectually disinfecting ships and all domiciliary *foci* of pestilent fevers.

No person can be more conscious than the author, that this paper but imperfectly answers the purpose for which it was designed. It bears its own impress of an effort to subsidize various elements of knowledge to purposes of public utility, — even before some of those elements have passed the crucible of rigid experiment and received the seal of scientific demonstration. Such as it is, the paper is submitted as a voluntary contribution to the good works undertaken by the National Sanitary and Quarantine Convention.

ELISHA HARRIS.

253 Fourth Avenue, New York,
June 12, 1860.

